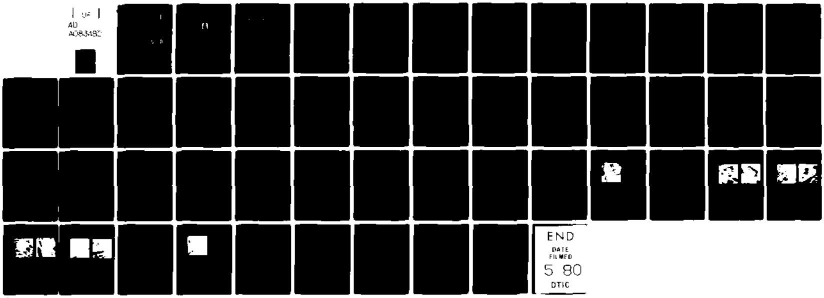
AD-A083 482 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OH F/G 17/2.1
GEOMETRIC METHODS OF PROCESSING TELEVISION IMAGES OF THE CLOUD --ETC(U)
NOV 79 K S SHIFRIN, Y S FRIDMAN
UNCLASSIFIED FTD-ID(RS)T-1407-79 NL



PHOTOGRAPH THIS SHEET

ADA083482

DTIC ACCESSION NUMBER

LEVEL

INVENTORY

FTD-ID(RS)T-1407-79

DOCUMENT IDENTIFICATION

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

DISTRIBUTION STATEMENT

ACCESSION FOR		
NTIS	GRA&I	☑
DTIC	TAB	☐
UNANNOUNCED		☐
JUSTIFICATION		
BY		
DISTRIBUTION /		
AVAILABILITY CODES		
DIST	AVAIL AND/OR SPECIAL	
A		

DISTRIBUTION STAMP

DTIC
ELECTE
S APR 29 1980 D
D

DATE ACCESSIONED

80 3 4 117

DATE RECEIVED IN DTIC

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDA-2

DTIC FORM OCT 79 70A

DOCUMENT PROCESSING SHEET

FTD-ID(RS)T-1407-79

FOREIGN TECHNOLOGY DIVISION

GEOMETRIC METHODS OF PROCESSING TELEVISION IMAGES
OF THE CLOUD COVER OF THE EARTH

by

K. S. Shifrin, Yu. S. Fridman

FTD-ID(RS)T-1407-79

UNEDITED MACHINE TRANSLATION

FTD-ID(RS)T-1407-79 6 November 1979

MICROFICHE NR. FTD-79-C-001465L

CSI71733348

GEOMETRIC METHODS OF PROCESSING TELEVISION IMAGES OF THE CLOUD COVER OF THE EARTH

By: K. S. Shifrin, Yu. S. Fridman

English pages: 44

Source: Trudy Glavnoy Geofizicheskoy Observatorii, Leningrad, Nr. 235, 1970, pp. 24-42.

Country of origin: USSR
This document is a machine translation.
Requester: FTD/TQTR
Approved for public release; distribution unlimited.

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

Page 24.

GEOMETRIC METHODS OF PROCESSING TELEVISION IMAGES OF THE CLOUD COVER OF THE EARTH.

§1. Introduction. Formulation of the problem.

K. S. Shifrin, Yu. S. Fridman.

Use of ISZ [artificial earth satellite] for meteorological observations placed before applied mathematics a whole series of new problems. One of such problems, about which will go the speech below, is the development of the mathematical method of treating the images of the cloud cover, obtained with the help of the television camera, situated on satellite. In spite of the large efforts/forces, spent on the development of other methods of obtaining the information about atmosphere, the television photographs of the cloud cover and of the earth's surface are the up to now only form of the information, actually utilized in the meteorological practice of the series/row of the countries. This information is of large interest, since form and cloudiness, structure of the fields of cloudiness, rotation of the

forms of cloudiness and their evolution can serve as basis for the diagnosis of macro- and mesoscale atmospheric processes. We are to a certain degree returned here to the idea of nephanalysis - the determination of a weather change in observations of cloudiness, but already at other, much higher level: at the level of the use of these meteorological satellites [2].

Each photograph of the cloud cover contains a colossal quantity of informational units. If we take into account also an enormous number of photographs of cloudiness, which continuously enter with ISZ, then it will become it is clear that here must be used the methods of machine working/treatment. According to the evaluation of Ye. K. Fedorov, the discussion deals with billions of information daily [1].

Up to now in essence from this entire enormous material are used separate photographs for weather analysis in especially complicated situations, when usual synoptic analysis proves to be ambiguous. This is done visually, by the examination of separate photographs. The methods of analysis are qualitative and suffer subjectivism. Although in a number of cases similar analysis is very useful, it is clear, however, that it cannot be comprehensive. It is necessary to study the mass characteristics of cloud formation/educations, their dynamics and statistics, to compare them with the ground-based data

and synoptic charts of area in question and period.

Page 25.

But as to fulfill a similar work with many thousands of photographs, which we do place?

It is obvious, for this it is necessary at first to learn to somehow preliminarily treat photographs, extracting of them basis and leaving aside secondary, unessential. Clearly also, that these methods of treating the photographs must be adapted to computers, which are capable of operationally fulfilling this working/treatment.

In the present work are presented the methods, which, as it seems to us, can be placed as the basis of the solution of this problem.

Each photograph of the cloud cover contains many different fine details, precise transfer and analysis of which actually are not necessary. This is the excess information (" informational noise"), which cannot be, in any case at present, rationally used. For the practical use of photographs entire information, which is contained in photograph, must be reduced to the limited, comparatively small number of integral characteristics. It is necessary to further study

statistics and dynamics of these characteristics, to trace their connection/communication with meteorological processes of macro- and mesoscale.

The correct selection of fundamental characteristics has important value. In different problems this selection can be different, hardly it is possible to propose anything universal. The more or less reliable system of characteristics, probably, it will be possible to obtain after the acquisition of adequate experience according to the analysis of photographs and studies of their connection/communication with meteorological processes. But it seems to us doubtless that as the basis of similar analysis must be placed the geometric characteristics of photograph - portion of the area, occupied with clouds, grain of cloud formation/educations, direction, degree of elongation and curvature of cloud bands, convexity and connectedness of separate cloud nuclei, etc. Problem is reduced to the development of the machine methods of determining the geometric characteristics of photographs.

Let us note that a similar problem arises also during the analysis of the radar traces of clouds and photographs.

For the analysis of television photographs were proposed series/row of the diagrams, based on the theory of random processes,

information theories and identification of forms [4-9]. Formally the problem of pattern recognition can be realized both by the determined way on the basis of certain of the sufficiently complete system of the parameters and with the help of the algorithms of recognition with stochastic instruction. In this article we propose the strictly formalized, or determined methods of the interpretation of photographs.

In view of the complexity of the forms of satellite photographs during the recognition of cloud systems without preliminary parametrization the requirements for the memory will considerably exceed the possibility of contemporary ETsVM [digital computer]. Furthermore, the determined instruction always is more reliable than stochastic.

The values of our parameters can be considered as the components of the vector function, determined in the space of data of the brightness of surface elements, moreover if this space has dimensionality on the order of thousands, then the dimensionality of the space of vector function does not usually exceed 10-15.

Page 26.

For machine working/treatment to photographs it is necessary to

give digital form. Image brightness at discrete/digital points can be obtained either by the method of photographic photometry or it is direct by TV signals from satellite. So that working/treatment of photographs in digital form would prove to be virtually appropriate, it is necessary to create the device/equipment, converting the analog TV signals, obtained directly from weather satellite, into discrete/digital signals in code representation for direct input/introduction into machine.

At present there is no generally accepted system of the classification of cloud images with ISZ, similarly, for example, accepted during ground observations. The comparison of these satellite and ground observations of cloud cover showed that the results of determining the cloudiness, as a rule, coincide satisfactorily, whereas the identifications of the forms of cloudiness frequently diverge. Satellite photographs, for example, usually do not make it possible to discover the scattered cumulus clouds and the thin translucent clouds of upper and average of tiers [2].

This question was in detail examined by J. Conover [10]. They proposed the detailed diagram of classification telev. ion of the photographs of clouds with ISZ (Fig. 1). According to this diagram the clouds are divided into two groups: the cloud of cumulus and

noncumulus forms, in turn, the clouds of each group are subdivided into banded and nonbanded. Then occurs the more detailed distribution of clouds in dependence on straightness and camber of bands, convexity and concavity of cloud nuclei for the clouds of cumulus forms, fibrousness and nonfibrousness of the clouds of noncumulus forms.

In this article are proposed the methods of the automatic determination of the parameters, which characterize the properties of the tele-photographs of cloudiness indicated. Of course the diagram of Conover is not universal. In work [3], for example, is proposed another classification of the photographs of the cloud systems, obtained by Soviet by the cosmonauts: clouds are subdivided into three basic groups.

The first group includes the clouds, which develop in uniform in its properties air mass, thus, for instance air-mass clouds. The second group includes the clouds, connected with the existence of cyclones. Into third group enter the clouds of jet streams, which appear with stable in the direction high winds.

We accepted the diagram of Conover, since it is sufficiently detailed and constructed on material of the television photographs, obtained from satellites. Let us emphasize that the described below

methodology is applied to any classifications based on the examination of the geometric special features/peculiarities of the photographs of the cloud cover of the Earth.

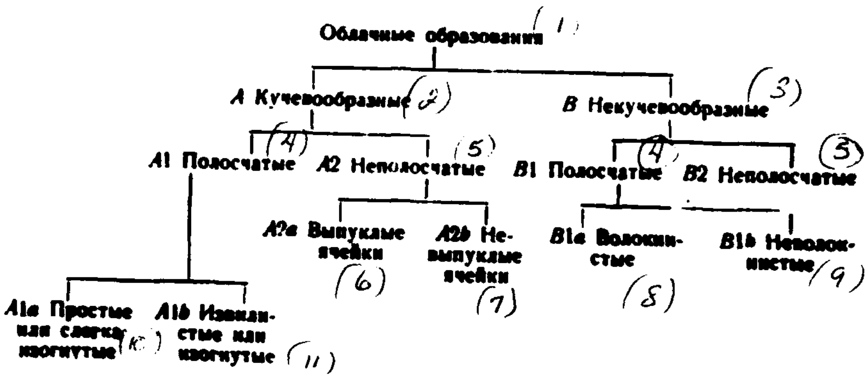


Fig. 1. Diagram of the classification of cloud photographs.

Key: (1). Cloud formation/educations. (2). Cumuliform. (3). Noncumulus. (4). Banded. (5). Nonbanded. (6). Convex nuclei. (7). Nonconvex nuclei. (8). Fibrous. (9). Nonfibrous. (10). Simple or slightly bent. (11). Winding or bent.

Page 27.

§2. Characteristics of photograph and the methods of their determination by ETsVM.

Let us consider the consecutively/serially different characteristics of photograph and let us point out the methods of their determination by ETsVM. In this case we will consider that the

photograph is given to digital form, i.e., to us is assigned the two-dimensional array of numerals - plane field of brightness.

a) machine room of background from cloudiness. The analysis of photograph begins with the isolation/evolution of cloudiness from background. Constant for all photographs of brightness value, which demarcates background and cloudiness, there does not exist, since image brightness one and the same of the underlying surface can strongly vary depending on different special features/peculiarities of survey and reconstruction of image. It is clear that as the criterion of discrimination it is not possible to take the average/mean value of brightness m_1, since it depends substantially on the portion of cloudiness and background.

Using m_1 as a border of distribution, let us erroneously depending on the sign of the measure of the obliquity of brightness distribution of photograph [14] to relate either the part of the cloud cover to background, or vice versa. A detailed examination of other different possibilities shows that for the criterion of distribution x it is expedient to take arithmetic mean value of the brightness of cloudiness and background of such black-white model whose dispersion of the brightness of the points, which belong to both the clouds and to background, is equal to zero. Conformity to model to real photograph is determined by the agreement in them of

three firsts of initial moments. Is not difficult to demonstrate that for any real photograph this model exists, only and not contradictory, if we for its first three initial ones of moment/torque take the actual initial moments/torques of this photograph. In [14] it is proved that $\dot{\varkappa}=m_1+1/2\ \alpha\sigma$, where for this photograph m_1 - average/mean value of brightness, α - measure of the obliquity of distribution, σ - basic deviation of distribution.

Let us note in conclusion that the advisability of use $\varkappa$ as the criterion of distribution is confirmed directly by experiment. The percentage of the cloudiness, determined by ETsVM, nearest of all to the evaluation of the cloudiness in photograph, obtained visually, when as the criterion of distribution accept number $\dot{\varkappa}$.

b) The development/detection of the ducts/contours of photograph. Different numerical characteristics of photograph, such as, for example, the measure of the grain size of photograph, the coefficient of cloud form (ratio of the square of perimeter to the area of cloud), the degree of elongation and camber of cloud bands, the measure of the convexity of the boundaries of clouds and many others, can be defined after they will be revealed and in the memory of machine preserved the object lines of the regions, occupied with clouds. After the isolation/evolution of background from cloudiness in the memory of machine have already been preserved all end-points,

but they are not yet regulated. The development/detection of duct/contour is equivalent to the indication of the order of the search of the following end-point, which belongs to the same duct/contour. In [16] is given detailed description of one of the simplest and easily realizable by ETsVM algorithms of the search of the sequence of the components/links of line of demarcation. After determining by consecutive scanning through line the first end-point, we further easily find the subsequent end-points, arranged/located so that during motion along duct/contour the cloud remains to the left, and background to the right relative to the direction of circuit/bypass. In [16] it is proved that the lines, revealed thus, are the locked, nonself-intersecting broken lines. It is obvious, that by varying the criterion of distribution, it is possible with the help of these algorithms to select not only the boundaries of clouds, but also different lines of level of brightness and thereby to trace the structure of isolatedes cloud.

Page 28.

c) The mutual location of the clouds of the level lines on isolatedes cloud. Are possible three different cases of the mutual location of two ducts/contours: L_1 within L_2, L_2 within L_1 and one duct/contour out of another. For brevity let us further differ these cases respectively marks $L_1 \overset{\varepsilon}{<} L_2$, $L_1 \overset{\varepsilon}{>} L_2$, $L_1 \sim L_2$, where ε takes two values:

+1 or -1 depending on the direction of the circuit/bypass of outer duct. Mark e indicates, the external or internal boundary of cloud is outer duct. Are possible five versions of the mutual location of object lines in photograph (Fig. 2). In accordance with known terminology let us name cloud multiply-connected, if within it is at least one spot of background, i.e., if it not continuous. A quantity of connectivity of this figure is called a number of its line ofs demarcation, or the increased per unit number of internal connected figures. For example, within a single-connection cloud of spots no background there is and respectively only one line of demarcation. Our all boundary curves, as it was said, are curves with right circuit/bypass for the appropriate cloud. Thereby for a background they are curves with left circuit/bypass.

The reciprocal location of ducts/contours can be distinguished with the help of Cauchy integral $\frac{1}{2\pi i}\oint_{L}\frac{dz}{z-\xi}$.

As is known, if ξ - external point of duct/contour, then this integral is equal to zero, if ξ - internal point of the figure, delineated by an outline, then integral with right bypass of duct/contour is equal to one, with left - is equal to -1.

The introduced earlier signs in the symbols of mathematical logic can be determined by the following formulas:

$$L_1 \overset{e}{>} L_0 \rightleftarrows L_1 \overset{e}{\cdot} L_1 \rightleftarrows \exists(\xi \in L_0) \times$$

$$\times \wedge \neg(\xi \in L_1) \wedge \left(\frac{1}{2\pi i}\oint_{L_1}\frac{dz}{z-\xi} = e\right); \quad e \in \{-1, +1\}.$$

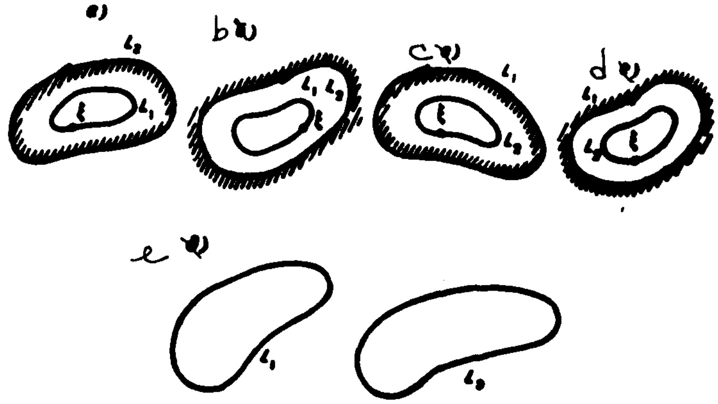


Fig. 2. Mutual location of clouds and level lines on isolatedes cloud.

a) $L_1 \overset{+1}{<} L_0$. b) $L_1 \overset{-1}{<} L_0$. c) $L_1 \overset{+1}{>} L_0$. d) $L_1 \overset{-1}{>} L_0$. e) $L_1 \sim L_0$.

Page 29.

Or by the words: relation $L_1 \overset{\bullet}{>} L_2$, equivalent $L_2 \overset{\bullet}{<} L_1$, means that there is such point ξ, which lies on duct/contour L_2 and not belonging to duct/contour L_1, for which the Cauchy integral on duct/contour L_1 is equal to $\bullet$.

Relation $L_1 \sim L_2$ means that L_1 does not lie/rest within L_2 and L_2 does not lie/rest within L_1

$$L_1 \sim L_2 \rightleftarrows \neg(L_1 \overset{\bullet}{<} L_2) \wedge \neg(L_2 \overset{\bullet}{<} L_1);$$
$$\bullet \in = \{-1, +1\}.$$

The question about the mutual location of ducts/contours arises in connection with the study of the properties, examined in

points/items d), e), k), l), and also during the calculation of area and perimeter of multiply-connected clouds.

d) the clouds of cumulus forms. Cumulus nature of cloud can be described by a number of bright spots, which fall per the unit of area of cloud, or, in other words, in the density of the location of bright spots on cloud. Bright spot we call the set of the points, which lie on cloud and having the brightness, which exceeds the brightness of adjacent points. These spots are mathematically lax local maximums, and it is possible to isolate them with the help of the lines of level of the field of brightness. One such maximum will be limited by the closed curve of level for which all internal points have brightness, not less than contour ones.

Let us note, however, that a number of bright spots insufficiently fully characterize cloud from point the views of its cumuliformity. For cumulus clouds characteristic is the specific rotation of bright and dark spots. Recently for studying laws governing the field of the brightness of photograph are developed/processed also other methods, in particular two-dimensional spectral analysis [5]. It is completely possible that during the identification of the clouds of cumulus forms these means can be employed additionally to the worked out by us geometric characteristics.

It should be noted that for the low-resolving photographs the cumuliform structure of isolated cloud usually is not discovered, so that the division of isolatedes cloud into the clouds of cumulus and noncumulus forms is related to photographs with sufficiently high resolution.

e) the determination of grain of the cloud cover. The grain size of photograph characterizes laws governing the location of clouds in photograph. It it is possible to numerically determine:

1) by the average/mean area of cloud grains, 2) by an average quantity of grains, which fall per the unit of area of photograph, 3) by the ranks of the distribution of cloud grains according to sizes/dimensions and by the moments/torques of these distributions.

f) convexity is the concavity of the boundaries of cloud nuclei. The point of convexity is this end-point, when on tangent to duct/contour in the vicinity of point of contact of tangency is contained not one internal points of cloudiness.

If cloud is bypassed from outer side, then convexity and concavity of boundary in certain of its section $M_1M_2M_3$ can be

determined by the sign of vector-scalar product $s=(\overline{M_1M_2}\times\overline{M_2M_3})\overline{n}$, where $\overline{n}$ - any fixed/recorded vector, perpendicular to the plane of figure. If we, for example, direct vector $\overline{n}$ on "us", then with the circuit/bypass of cloud from without counterclockwise in the section of convexity the three of vectors $\overline{M_1M_2}$, $\overline{M_2M_3}$, $\overline{n}$ will prove to be by rightist and number s will be more than zero, in the section of concavity - by left and $s<0$. As the criterion of the convexity of cloud nuclei can serve the relation of the part of the perimeter of cloud, in which is broken the convexity, to entire perimeter of this cloud.

Page 30.

For the measure of the convexity of figure it is possible to take also the ratio of its area to the area of the smallest convex hull, which contains this figure.

If the smallest convex hull will be already found in connection with other geometric special features/peculiarities of photograph, then the latter of two methods of determining the measure of convexity proves to be more rational.

g) direction and measure of the elongation of cloud band. For the direction of the elongation of this figure it is possible to take

either the direction of its greatest chord, if it is alone, or direction of the larger side of the described about it rectangle, which has minimum area.

When maximum chord not only, for the numerical estimate of the magnitude and direction of elongation let us introduce the concept of the flat/plane cone of the maximum directions, or of director cone. This smallest of the locked cones whose boundary directions are directions of the maximum chords and out of which there is not one direction of maximum chord. In the particular case when maximum chord only one, cone consists of one direction. For the direction of elongation it is possible to take any direction from director cone, for example his axis of symmetry.

For the characteristic of the measure of elongation we will use the concept of line of support for this figure. Line of support relative to the locked duct/contour is called the straight line, which has with it although one common point and passing not through one internal point of the figure, limited by this duct/contour.

By the quantitative index of elongation can serve one of the following relations:

1) the ratio of the minimum distance between parallel lines of

support to the length overall chord;

2) distance ratio between the lines of support, parallel to certain direction of director cone, to the length overall chord;

3) the ratio of the minimum distance between parallel lines of support to the distance between the lines of support, perpendicular to this pair;

4) distance ratio between pairs lines of support, parallel to certain direction of director cone, to the distance between supporting/reference ones, perpendicular ones to this pair;

5) the relation of the sides of minimum by area described rectangle.

(As shown by us, for the sufficiently elongated figures for the index of the measure of elongation it is possible to take any of these characteristics).

We recommend for the index of elongation the accepting of distance ratio between the lines of support, parallel to the bisectrix of director cone, to the distance between supporting/reference ones, perpendicular ones to this pair, since

this characteristic, usually more easily in all to determine by our ETsVM.

Page 31.

We have evaluated the maximum mutual disagreement of these characteristics is proved their interchangeability for the strongly elongated figures.

Are established/installed the following inequalities:

1. $$l > d\cos(\widehat{l,d});$$
$$\frac{1}{2} < \frac{r}{l} < 1,$$

where d - the length overall chord, r - a minimum distance between parallel lines of support, l - distance between the lines of support, parallel to certain direction of director cone.

2. Angle, comprised by larger side of minimum described rectangle with maximum chord, does not exceed

$$\frac{1}{2}\arcsin 2\frac{r}{d}.$$

3. Ratio of area of minimum described rectangle S_{min} to area S of rectangle, one of sides of which coincides with certain direction from director cone, is not less

$$\frac{1}{2}\cos\left(\frac{1}{2}\arcsin 2\frac{r}{d}\right).$$

4. Ratio of area S' of described rectangle, one pair of sides of which realizes minimum distance between parallel lines of support, to smallest area of described rectangle does not exceed $\sqrt{2}$.

$$1 < \frac{S'}{S_{min}} \leqslant \sqrt{2}.$$

5. If director cone has apex angle γ, then large side of minimum described rectangle deviates from middle of this cone to angle

$$\psi \quad \frac{1}{2}\arcsin 2\frac{r}{d} - \frac{\gamma}{2}.$$

These theorems and evaluations are valid for convex figures. For nonconvex figures logical for the index of the direction of elongation to acquire the natures of the elongation of the smallest convex hull of this figure, since for this figure and its convex hull all lines of support will be general/common/total.

h) the striation of cloud systems. As the line, which characterizes elongated cloud band, logical to take the locus of the middles of chords, perpendicular either to the direction of the elongation of cloud, or to its boundaries.

Normal straight line at the particular point of the boundary of cloud let us name the straight line, passing through this point

perpendicular to the chord, which combines the points of boundary, close to data. In order to eliminate chance in the parts of the duct/contour and of the errors, connected with transition/transfer from the duct/contour of boundary to the broken line of the experimental data of brightness, it is expedient as close to this end-point to consider not adjacent points, but distant behind it at certain permanent for a photograph distance $\pm\delta$. The length of this segment δ is connected with the sizes/dimensions of the elementary areas/sites and the degree of the crookedness of the boundaries of clouds. Normal chord at the particular point of boundary we will call the segment of normal the straight line, which lies within cloud and which combines this end-point with any another point of the boundary of cloud. Since in the memory of machine for each cloud is preserved the sequence of its end-points, then for each end-point of singly connected ducts/contours easily succeeds in finding opposite end and length of this standard. Arithmetic mean value of the lengths of normal chords can be named the width of cloud.

Page 32.

The locus of the middles of these normal chords we will consider as the center line of cloud. The ratio of the width of cloud to the length of its center line is the characteristic of the degree of the elongation of cloud. Fibrousness of cloud we consider as the banded

clouds of the strongly elongated form.

If for this cloud the direction of elongation by ETsVM is already found, then as the line, characterizing the band, has sense to take the locus of the middles of chords, perpendicular to the direction of elongation. For the bandwidth it is possible to take the ratio of the area of figure to the length of this line, which characterizes band. If the bandwidth is plotted/deposited at each point of the which characterizes lines in the direction normal to it then is formed the strip figure, in known sense which substitutes data. This approximation/approach indicates the replacement of figure by the band, obtained as a result of central-similar transformation of the characteristic line. For each point the curved center of transformation is the center of curvature of curve at this point, and edge bands defend from this curved at a distance, equal to 1/2 widths band.

i) camber and crookedness of cloud bands. The camber of cloud bands can be characterized by the average/mean value of the absolute degree of curvature of line, which characterizes band, and crookedness - by number of changes in the sign of the curvature of this center line.

For the characteristic of the degree of the camber of band we

propose to compute the curvature of its central line according to the following approximation formula:

$$K = \frac{r_{+h} + r_{-h} - 2r}{h^2},$$

where $\bar{r}$ - radius-vector of the point, at which is computed the curvature, $\bar{r}_{+h}$ and $\bar{r}_{-h}$ – radius-vectors of points curved, distant from this on $\pm h$, h - a sufficiently low positive value.

If by curve is accepted right index, then in the section of the convexity of vector $r - r_{-h}$ and $r_h - r$ they must compose right pair, for the points of nonconvexity - left, which is easy to come to light/detect/expose by determinant sign

$$D = \begin{vmatrix} x - x_{-h} & y - y_{-h} \\ x_h - x & y_h - y \end{vmatrix}$$

Using the determinant D indicated, it is possible the curvature of curve to approximately compute according to the simpler formula

$$K = \lim_{h \to 0} \frac{D}{h^3}.$$

k) bright lines from clouds (cloud street). In the photographs of cloudiness frequently is discovered a whole series of characteristic parts. Their number includes first of all the so-called cloud ridges/ranges or the streets, which are the regular arrays of cumulus clouds. In this paragraph is examined the possibility of the formal determination of such special

features/peculiarities of the method of photography.

Small/fine clouds can be considered as the low vicinities of the local maximums, which lie on bright lines. Since at the points of maximum $dz=0$, $\Delta z<0$, then of the relationship/ratio $\Delta z \approx (1/2) d^2z$ follows that in extreme point and its vicinity d^2z is fixed-sign negative quadratic form from dx and dy.

Page 33.

In view of this, in a sufficiently small vicinity of the extremum of the line of level of brightness they are locked, everywhere convex relative to the internal points of this vicinity and in the first approximation, they can be considered as ellipses. In all photographs in which we had the capability to observe bright lines from clouds, their ellipsoidality and elongation along the bright lines, containing them, were confirmed.

As the criterion of the fact that the obtained sequence of clouds actually/really forms line, can serve the permanent or slowly changing angle between the directions of their elongation and sufficient density of clouds on it. Let us consider one of the possible methods of the search of the nearest small cloud, through which passes the same bright line.

Place are axis ox along the direction of elongation. k - index of elongation for this cloud. We affinely convert photograph, after pressing it along the direction of elongation into k times, i.e., let us introduce the new coordinates $x'=xk$, $y'=y$. Then cloud loses the property of elongation and, therefore, vanishes one of the criteria of checking the continuation of line, but bright line during visual observation will become still brighter and clouds on it will be placed more densely. Then one should expect that the near cloud to data will lie/rest on this line and the passage of line it is necessary to seek on the minimum of usual, i.e., circular, metric $\mu^2=x'^2+y'^2$. Near obtained from this metric cloud, which satisfies by the criterion of continuation, can be considered the continuation of the unknown line.

1) cyclonic vortices/eddies. The peculiar spiral-shaped systems of cloudiness (vortices/eddies), connected with strong blinds, are one of the distinctive special features/peculiarities of the distribution of cloudiness according to terrestial globe. It is possible to mathematically come to light/detect/expose them in the photographs of clouds, tracing the form of cloud ridges/ranges and extremal lines on isolatedes cloud. For the automated detection of extreme lines and connected with them vortices/eddies there can be

their used following formal determination. Bright line - is the line whose individual sections are the gradient lines of the field of brightness and which comes only through the points of the greatest curvature of the sections of the convexity of the level lines from the carrier brighter part of the cloud. It is in more detail about this it is possible to read in [9].

If to any special of photograph (to pole) descend several bright open-circuited and not intersecting lines, along which the vectorial angle with apex/vertex in pole varies monotonically, then this singular point is the center of vortex/eddy, if the curvature of bright line in pole reaches a sufficient value, also, during motion along extremal monotonically and intensely it grows.

Page 34.

§3. Test work of methods.

For illustration of developed ones methods we carried out the analysis of 10 television photographs of cloudiness, obtained with ISZ "Tiros-7". Photographs[1] were not attached to concrete/specific/actual area and moment of time, so that we could not fulfill the meteorological analysis of these photographs.

FOOTNOTE [1]. Photographs were given to us by the senior research associate of TsIP R. F. Usmanov in 1964 the authors sparking prize. they were body to it for this. ENDFOOTNOTE.

Photographic films of cloudiness were processed on microphotometer MF-2 in the laboratory of aerial methods. Taking into account the distortions of brightness on the boundaries of sequence, by photometric measurement was produced the scanning only within the framework, carried out at a distance of 2 mm from each edge. Size/dimension of the internal part of the framework 20x20 mm. The diameter of ray/beam was undertaken equal to 200 μ, and lines were carried out with interval in 200 μ. Thus, in all on sequence were

placed approximately/exemplarily 50 lines. From microphotometer the data about brightness entered in the form of smooth curves. Further these graphs in the division of radiation research of Main Geophysical Observatory were converted into the two-dimensional arrays of numerals. For this in each line of the diagram through equal gaps/intervals by hand were removed/taken the values of brightness according to the conditional uniform twenty-four point scale. For the first five photographs the intervals between two adjacent readings were undertaken doubly smaller than for the others. Those obtained thus 10 two-dimensional arrays of numerals were transmitted for adjustment and transmission of the program, written in international algorithmic tongue "ALGOL-60", by ETsVM M-20. For each of 10 photographs there was made the following statistical analysis (Fig. 3):

1) were obtained data summary and ranks of brightness distribution;

2) were found minimum ξ_{min} and maximum ξ_{max} of brightness value, average/mean value m_1, the value of our criterion of distribution $\varkappa$, dispersion σ^2, measure of the obliquity of distribution α;

3) were found the portions of cloudiness p and background q on photograph, corresponding to criterion $\varkappa$;

4) separately for clouds and background were found average/mean values, dispersion and measure of obliquity.

As it was noted in point/item a) the second paragraph, proposed by us criterion $\varkappa$ is not the only possible.

In order to consider the quality of criterion $\varkappa$ and to compare it with others, during April 1966 was set special statistical experiment, 100 to observers (which were the students of the 1st course of chemico-technological factorial of forestry academy) it gave 9 tele-photographs of the cloudiness (10th sequence at this time was in work) and they proposed to visually consider the portion of the area, occupied with cloudiness on the produced photograph, and to register the result of observation. Arithmetic mean from these results for each photograph was accept as the visually observed portion of cloudiness ($p_{\text{виз.}}$).

Table 1. Comparison of the criteria of distribution.

(1) Номер снимка	$p_{виз}$	$p(m_1)$	$\Delta(m_1)$	$\Delta^2(m_1)$	$p(\xi_{2M})$	$\Delta(\xi_{2M})$	$\Delta^2(\xi_{2M})$	$p(x)$	$\Delta(x)$	$\Delta^2(x)$
1	0,22	[illegible]	[illegible]	0,017	0,18	0,04	0,002	0,23	0,01	0,000
2	0,61	0,50	0,11	0,011	0,52	0,09	0,007	0,50	0,11	0,012
3	0,44	0,40	0,01	0,002	0,40	0,04	0,002	0,38	0,06	0,004
4	0,16	[illegible]	0,19	0,038		—	—	0,19	0,03	0,001
5	0,53	0,47	0,06	0,004			—	0,45	−0,08	0,006
6	0,43	0,40	0,03	0,0?0	—		—	0,42	−0,01	0,000
7	0,20	0,36	0,16	0,026		—		0,22	0,02	0,000
8	0,06	0,41	0,36	0,125	—	—	—	0,13	0,08	0,006
9	0,19	0,32	0,13	0,019			—	0,16	−0,03	0,008
(2) Среднее	[illegible]	0,40	0,19	0,027	0,37	0,06	0,04	0,30	−0,15	0,003

Key: (1). Number of photograph. (2). Average/mean.

Page 35.

In Table 1 are compared the portions of cloudiness, found from different criteria of distribution. In this table are accepted the following designations: ξ_{2M} the least frequency value of brightness, which lies between two modal values, $p(m_1)$ and $p(\xi_{2M})$, $p(x)$ the portions of cloudiness, found from brightness distribution, when as the criterion of distribution are accepted respectively m_1, ξ_{2M}, x.

The analysis of table is shown:

1) criterion ξ_M is applicable far not for all photographs, since brightness distribution for a majority of them is not two-modal;

2) during the evaluation of the portion of cloudiness $\varkappa$ as the criterion of distribution has explicit advantage before m_1;

3) most reliable criterion, in our opinion, is criterion $\varkappa$. It is theoretically substantiated, virtually easily it is computed, possesses by many interesting properties [8], gives satisfactory agreement $p(\varkappa)$ with p_m.

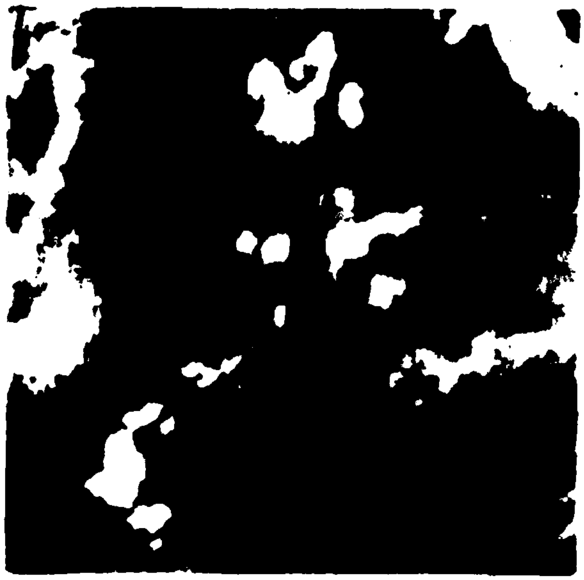


Fig. 3a. Results of statistical processing of photographs by ETsVM. Sequence 1.

Характеристика (1)	Обозначение (2)	Кадр (3)				
		1	2	3	4	5
Среднее значение яркости снимка (4)	m_1	7,51	9,41	7,97	5,81	9,33
Доля облачности снимка (5)	p	0,23	0,50	0,38	0,19	0,45
Доля фона (6)	q	0,77	0,50	0,62	0,81	0,55
Дисперсия яркости снимка (7)	σ^2	29,4	16,9	20,8	11,0	15,2
Мера косости распределения яркости снимка (8)	γ	1,21	4,21	0,46	1,39	0,30
Среднее значение яркости облачной части снимка (9)	m_1	16,2	13,0	13,0	11,7	13,0
Среднее значение яркости фона (10)	$\tilde{m}_1$	4,86	5,79	4,89	4,44	6,31
Дисперсия яркости облачной части снимка (11)	σ^2	12,6	3,95	5,94	5,48	5,23
Дисперсия яркости фона (12)	$\tilde{\sigma}^2$	4,60	3,61	4,78	2,33	3,34

Key: (1). Characteristic. (2). Designation. (3). Sequence. (4). Average/mean value of brightness of photograph. (5). Portion of cloudiness of photograph. (6). Portion of background. (7). Dispersion

of brightness of photograph. (8). Measure of obliquity of brightness distribution of photograph. (9). Average/mean value of brightness of cloud part of photograph. (10). Average/mean value of brightness of background. (11). Dispersion of brightness of cloud part of photograph. (12). Dispersion of brightness of background.

Page 36.

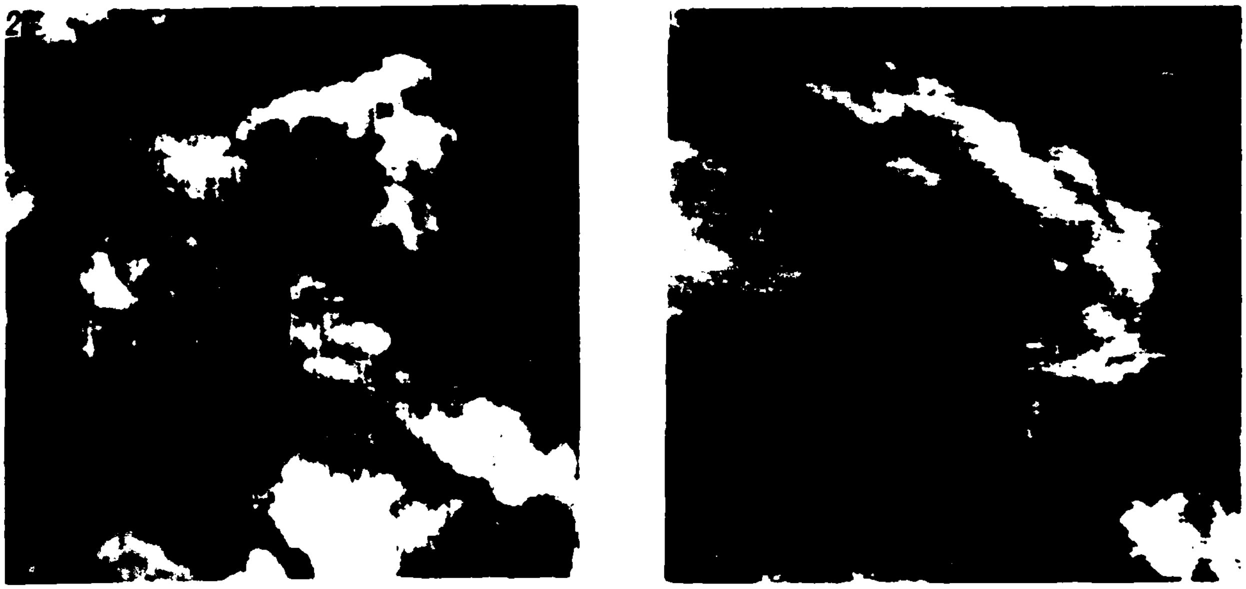


Fig. 3b. Results of statistical processing of photographs by ETsVM. Sequence 2 and 3.

Page 37.

Fig. 3c. Results of statistical processing of photographs by ETsVM. Sequence 4 and 5.

Page 38.

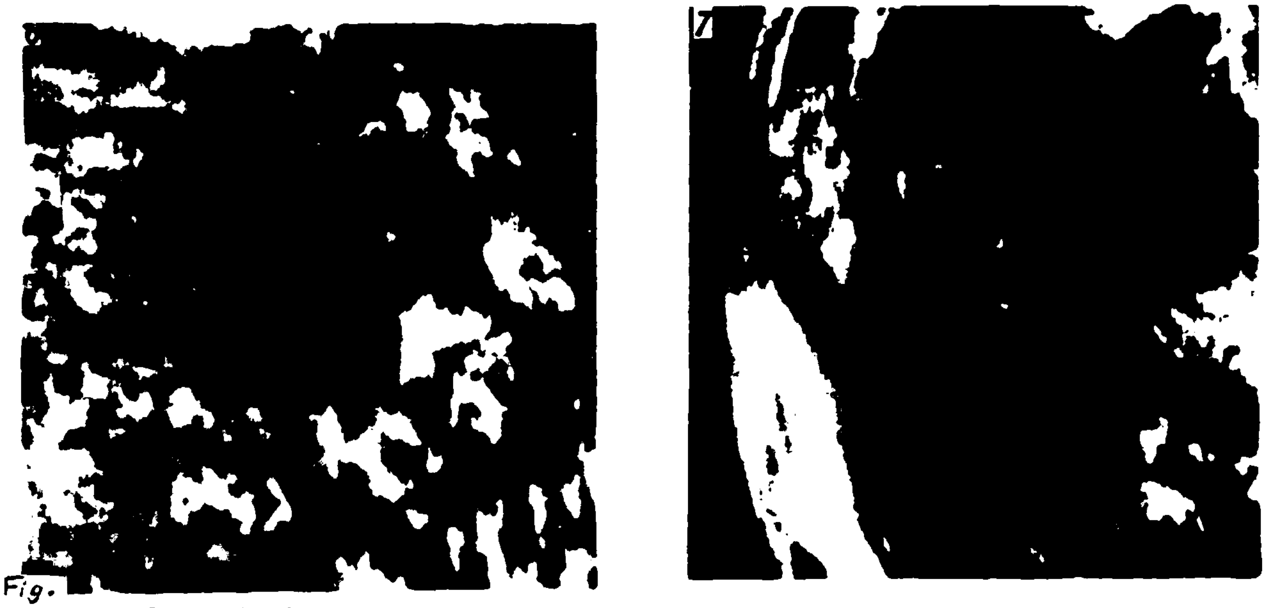


Fig. 4a. Results of the classification of photographs on diagram in Fig. 1.

(1) Кадр 6

Доля облачности A = 0,418 (2)

A1a = 0, A1в = 0,68 | A1 = 0,68 | A = 0,68
A2a = 0, A2в = 0 | A2 = 0
B1a = 0,05, B1в = 0 | B1 = 0,05, B2 = 0,27 | B = 0,32

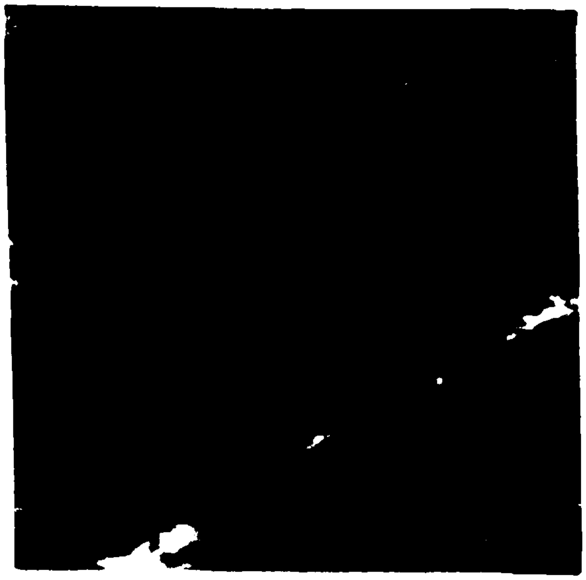
Кадр 7 (1)

A = 0,216

A1a = 0, A1в = 0 | A1 = 0 | A = 0
A2a = 0, A2в = 0 | A2 = 0
B1a = 0,053, B1в = 0 | B1 = 0,053, B2 = 0,947 | B = 1,0

Key: (1). Sequence. (2). Portion of cloudiness.

Page 39.



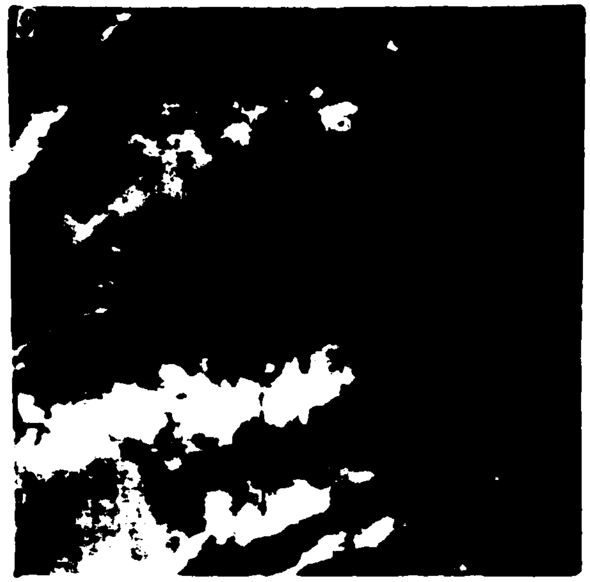


Fig. 4b. Results of classification of photographs on diagram in Fig. 1.

(1)

(1)

Key: (1). sequence.

Page 40.

The results of the classification of photographs are given in Fig. 4. Letters A, B, A1, A2, ..., A1a, A1b,... are for each photograph the portion of the cloudiness, which belongs to the class of the same designation.

Working/treatment of one sequence according to our program of classification occupies 20-30 s, data inputs from punched cards 1-2 min., translation from tongue "ALGOL-60" 15-25 min.

If data input subsequently will be produced directly by signals from satellite, then this will occupy approximately/exemplarily 5 s. In this case will be reduced the manual survey of ordinates with oscillograms and their translation/conversion into punched card, i.e., that which makes unsuitable the machine working/treatment of photographs.

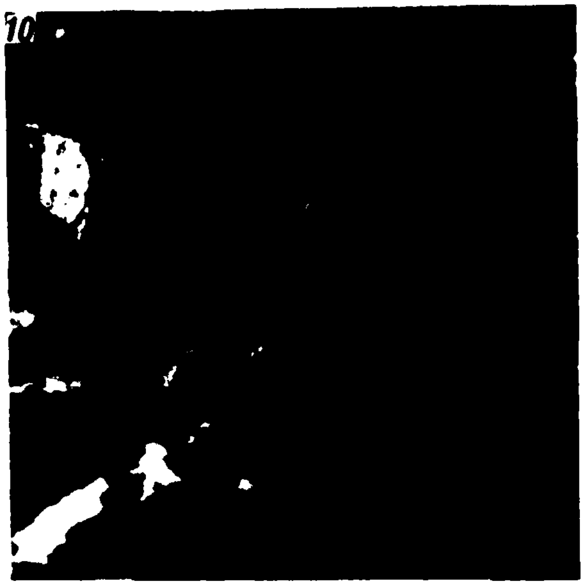
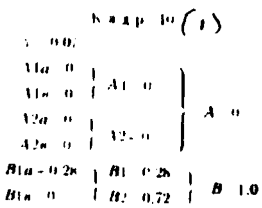


Fig. 4c. Results of the classification of photographs on diagram in Fig. 1.



Key: (1). sequence.

Page 41.

When selecting of the dimensionless parameters, which characterize stratification, convexity, fibrousness, we proceeded

directly from obtaining visually of representations relative to cloud species, belonging to this class. For example, cloud was related to banded ones, if the ratio of the width of cloud to the length of the characteristic line exceeded 1/4, to convex ones were referred those clouds for which the ratio of the nonconvex part of the duct/contour to entire duct/contour did not exceed 1/3, etc. The dimensional parameters a number of local maximums, which fall per unit of area, and average/mean curvature - did not have simple demonstrative sense and moreover, they were connected with the scales of photograph. For mining the criteria of cumuliformity and curvature of bands they entered as follows. For one of the frames/personnel they visually determined the percentage of the clouds, belonging to the appropriate class. Then all clouds in photograph were arranged/located in the ascending order of the parameter, with which was connected the division into classes, and with the help of computer is found this value of the parameter for which the accumulated sum of the areas of clouds was equal to the appropriate sum, evaluated visually for this cloud.

As a result were obtained the following values of criteria:

[illegible] (1)
[illegible] (2)
[illegible] (3)
[illegible] (4)
[illegible] (5)

Key: (1). for cumuliformity. (2). striation. (3). camber. (4). convexity. (5). narrowness of band.

Let us note that the numerical values of the parameters are given as an example. They should not be considered as them recommendations. The reliable values of these criteria can be obtained on the basis of working/treatment of photographs in a mass quantity. Only after the statistical check of the parameters and their numerical criteria it will be possible to rely on the practical value of the classification of photographs. Let us emphasize that the proposed diagram does not depend on the numerical values of the parameters, separating photographs into classes.

Conclusion.

In the work are proposed some geometric methods of the study of cloud form on meteorological photographs. Of course they are not the only possible and comprehensive. In view of complexity and diversity of the forms of cloud systems on meteorological photographs should be to first decrease a quantity of let by photograph information, "pressed" its introduction of parameter system of the form of isolatedes cloud and their mutual location. After placing this system of geometric parameters as the basis of classification it is possible then to pass to the solution of the problem of the identification of

forms and to the evaluation of the reliability of the diagrams of classification.

Whatever numerical characteristics of criteria were accepted into the basis of classification, are theoretically possible the cases of the essential disagreement of the obtained results of machine division into classes with visual representations. In view of the fact that to cloud form in photographs were placed no limitations, geometric methods do not give the possibility to consider, great disagreement between the calculated and visual evaluations, or frequency of the essential disagreements between them. All this is located in the scope of statistical methods.

Page 42.

Page 42.

Literature.

1. Федоров Е. К. Некоторые итоги выполнения плана научно-исследовательских работ за 1966 г. и перспективы научных исследований в новой пятилетке. Метеорология и гидрология, № 6, 1967.

2. Кондратьев К. Я., Борисенков Е. П. Морозкин А. А. Практическое использование данных метеорологических спутников. Гидрометеоиздат, Л., 1966.

3. Кондратьев К. Я., Крошкин М. Г., Морачевский В. Г. Наша планета из космоса. Альбом фотографий. Под общ. редакцией акад. Е. К. Федорова. Гидрометеоиздат, 1964.

4. Сонечкин Д. М. О дешифрировании телевизионных изображений облачности, полученных с искусственных спутников. Метеорология и гидрология, № 9, 1962.

5. Малкевич М. С., Монин А. С., Розенберг Г. В. Пространственная структура поля излучения как источник метеорологической информации. Изв. АН СССР, сер. геофиз., № 3, 1964.

6. Малкевич М. С. и др. Определение статистических характеристик радиационных полей над облаками. Космические исследования, том II, вып. 2, 1964.

7. Сонечкин Д. М., Тряпицына Н. С. Некоторые результаты исследования статистической структуры облачности. Труды ГМЦ, вып. 11, 1967.

8. Сонечкин Д. М. О сравнимости спутниковых и наземных [illegible] ных об общем количестве облаков. Труды ГМЦ, вып. 11, 1967.

9. Латышева В. И., Мельникова Т. А., Сонечкин Д. М. Использование телевизионного сигнала для определения количества и форм облаков на снимках, получаемых с метеорологических спутников. Труды ММЦ, вып. 11, 1966.

10. Conover I. H. Interpretation of clouds and mesoscale cloud patterns as seen from satellite altitudes. AFC[illegible] № 81, 1962.

11. Истомина Л. Г., [illegible]злов Е. М. О двумерной пространственной структуре яркости облачных полей. Изв. АН СССР. Физика атмосферы и океана, том. IV, № 7, М., 1968.

12. Фридман Ю. С. Машинная параметризация и классификация телевизионных изображений облачных систем. Материалы научно-технической конференции ЛТА, вып. V, 1966.

13. Фридман Ю. С., Гольдин В. Е. Параметризация телевизионных изображений облачности на электронных цифровых вычислительных машинах. Труды ГГО, вып. 196, 1966.

14. Фридман Ю. С. Математическая обработка телевизионных изображений облачного покрова Земли. Труды ГГО, вып. 203, 1967.

15. Фридман Ю. С. Яркие линии на облачных снимках. Материалы научно-технической конференции ЛТА. 1967.

16. Фридман Ю. С. Автоматизированная обработка снимков облачного покрова Земли, представленных в цифровой форме. Материалы научно-технической конференции ЛТА. 1968.

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION		MICROFICHE	ORGANIZATION		MICROFICHE
A205	DMATC	1	E053	AF/INAKA	1
A210	DMAAC	2	E017	AF/RDXTR-W	1
B344	DIA/RDS-3C	9	E403	AFSC/INA	1
C043	USAMIIA	1	E404	AEDC	1
C509	BALLISTIC RES LABS	1	E408	AFWL	1
C510	AIR MOBILITY R&D LAB/FIO	1	E410	ADTC	1
C513	PICATINNY ARSENAL	1		FTD	
C535	AVIATION SYS COMD	1		CCN	1
C591	FSTC	5		ASD/FTD/NIIS	3
C619	MIA REDSTONE	1		NIA/PHS	1
D008	NISC	1		NIIS	2
H300	USAICE (USAREUR)	1			
P005	DOE	1			
P050	CIA/CRB/ADD/SD	2			
NAVORDSTA (50L)		1			
NASA/NST-44		1			
AFIT/LD		1			
LLL/Code L-389		1			
NSA/1213/TDL		2			